SECTION

3.3

LIMITED APPLICATION STRUCTURAL STORMWATER CONTROLS

Regular inspection and maintenance is critical to the effective operation as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.3.1 Filter Strip

Limited Application
Structural Stormwater Control

Description: Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff from and remove pollutants through vegetative filtering and infiltration.

REASONS FOR LIMITED USE	STORMWATER MANAGEMENT SUITABILITY
• Cannot alone achieve the 80% TSS removal target **KEY CONSIDERATIONS** • Runoff from an adjacent impervious area must be evenly distributed across the filter strip as sheet flow • Can be used as part of the runoff conveyance system to provide pretreatment • Can provide groundwater recharge • Reasonably low construction cost • Large land requirement • Requires periodic repair, regrading, and sediment removal to prevent channelization	☑ **Water Quality** ☐ **Channel / Flood Protection** **SPECIAL APPLICATIONS** ☑ **Pretreatment** ☐ **High Density / Ultra-Urban** ☑ **Other:** Use in buffer system; treating runoff from pervious areas **Residential Subdivision Use:** *Yes*

3.3.1.1 General Description

Filter strips are uniformly graded and densely vegetated sections of land, engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer, or as pretreatment for another structural stormwater control. Filter strips can serve as a buffer between incompatible land uses, be landscaped to be aesthetically pleasing, and provide groundwater recharge in areas with pervious soils. Filter strips are often used as a stormwater site design credit (see Section 1.4 for more information).

Filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a significant reduction in runoff volume for smaller flows that infiltrate pervious soils while contained within the filter strip. To be effective, however, sheet flow must be maintained across the entire filter strip. Once runoff flow concentrates, it effectively short-circuits the filter strip and reduces any water quality benefits. Therefore, a flow spreader must normally be included in the filter strip design.

There are two different filter strip designs: a simple filter strip and a design that includes a permeable berm at the bottom. The presence of the berm increases the contact time with the runoff, thus reducing the overall width of the filter strip required to treat stormwater runoff. Filter strips are typically an on-line practice, so they must be designed to withstand the full range of storm events without eroding.

3.3.1.2 Pollutant Removal Capabilities

Pollutant removal from filter strips is highly variable and depends primarily on density of vegetation and contact time for filtration and infiltration. These, in turn, depend on soil and vegetation type, slope, and presence of sheet flow.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 50%**
- **Total Phosphorus – 20%**
- **Total Nitrogen – 20%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – 40%**

3.3.1.3 Design Criteria and Specifications

General Criteria

- Filter strips should be used to treat small drainage areas. Flow must enter the filter strip as sheet flow spread out over the width (long dimension normal to flow) of the strip, generally no deeper than 1 to 2 inches. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). For longer flow paths, special provision must be made to ensure design flows spread evenly across the filter strip.
- Filter strips should be integrated within site designs.
- Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.
- Filter strips should be designed for slopes between 2% and 6%. Greater slopes than this would encourage the formation of concentrated flow. Flatter slopes would encourage standing water.
- Filter strips should not be used on soils that cannot sustain a dense grass cover with high retardance. Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods. See Appendix F for a list of appropriate grasses for use in Georgia.
- The filter strip should be at least 15 feet long to provide filtration and contact time for water quality treatment. 25 feet is preferred (where available), though length will normally be dictated by design method.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.
- An effective flow spreader is to use a pea gravel diaphragm at the top of the slope (ASTM D 448 size no. 6, ⅛” to ⅜”). The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Other types of flow spreaders include a concrete sill, curb stops, or curb and gutter with “sawteeth” cut into it.
- Ensure that flows in excess of design flow move across or around the strip without damaging it. Often a bypass channel or overflow spillway with protected channel section is designed to handle higher flows.
- Pedestrian traffic across the filter strip should be limited through channeling onto sidewalks.

- Maximum discharge loading per foot of filter strip width (perpendicular to flow path) is found using the Manning's equation:

$$q = \frac{0.00236}{n} Y^{\frac{5}{3}} S^{\frac{1}{2}} \tag{3.3.1}$$

Where: q = discharge per foot of width of filter strip (cfs/ft)
Y = allowable depth of flow (inches)
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient
(use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

- The minimum length of a filter strip is:

$$W_{fMIN} = \frac{Q}{q} \tag{3.3.2}$$

Where: W_{fMIN} = minimum filter strip width perpendicular to flow (feet)

Filter without Berm

- Size filter strip (parallel to flow path) for a contact time of 5 minutes minimum
- Equation for filter length is based on the SCS TR55 travel time equation (SCS, 1986):

$$L_f = \frac{(T_t)^{1.25} (P_{2-24})^{0.625} (S)^{0.5}}{3.34n} \tag{3.3.3}$$

Where: L_f = length of filter strip parallel to flow path (ft)
T_t = travel time through filter strip (minutes)
P_{2-24} = 2-year, 24-hour rainfall depth (inches)
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient
(use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

Filter Strips with Berm

- Size outlet pipes to ensure that the bermed area drains within 24 hours.
- Specify grasses resistant to frequent inundation within the shallow ponding limit.
- Berm material should be of sand, gravel and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02"-0.04", Gravel: AASHTO M-43 ½" to 1").
- Size filter strip to contain the WQ_v within the wedge of water backed up behind the berm.
- Maximum berm height is 12 inches.

Filter Strips for Pretreatment

- A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a filter strip as a pretreatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Table 3.3.3-1 provides sizing guidance for bioretention filter strips for pretreatment.

Parameter	Impervious Areas				Pervious Areas (Lawns, etc.)			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (max = 6%)	< 2%	> 2%	< 2%	> 2%	< 2%	> 2%	< 2%	> 2%
Filter strip minimum length (feet)	10	15	20	25	10	12	15	18

Table 3.3.1-1 Bioretention Filter Strip Sizing Guidance
(Source: Claytor and Schueler, 1996)

3.3.1.4 Inspection and Maintenance Requirements

Activity	Schedule
• Mow grass to maintain a 2- to 4-inch height.	Regularly (frequently)
• Inspect pea gravel diaphragm for clogging and remove built-up sediment • Inspect vegetation for rills and gullies and correct. Seed or sod bare areas. • Inspect to ensure that grass has established. If not, replace with an alternative species.	Annual Inspection (Semi-annual first year)

Table 3.3.1-2 Typical Maintenance Activities for Filter Strips
(Source: CWP, 1996)

Additional Maintenance Considerations and Requirements

- Filter strips require similar maintenance to other vegetative practices. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice.

3.3.1.5 Example Schematic

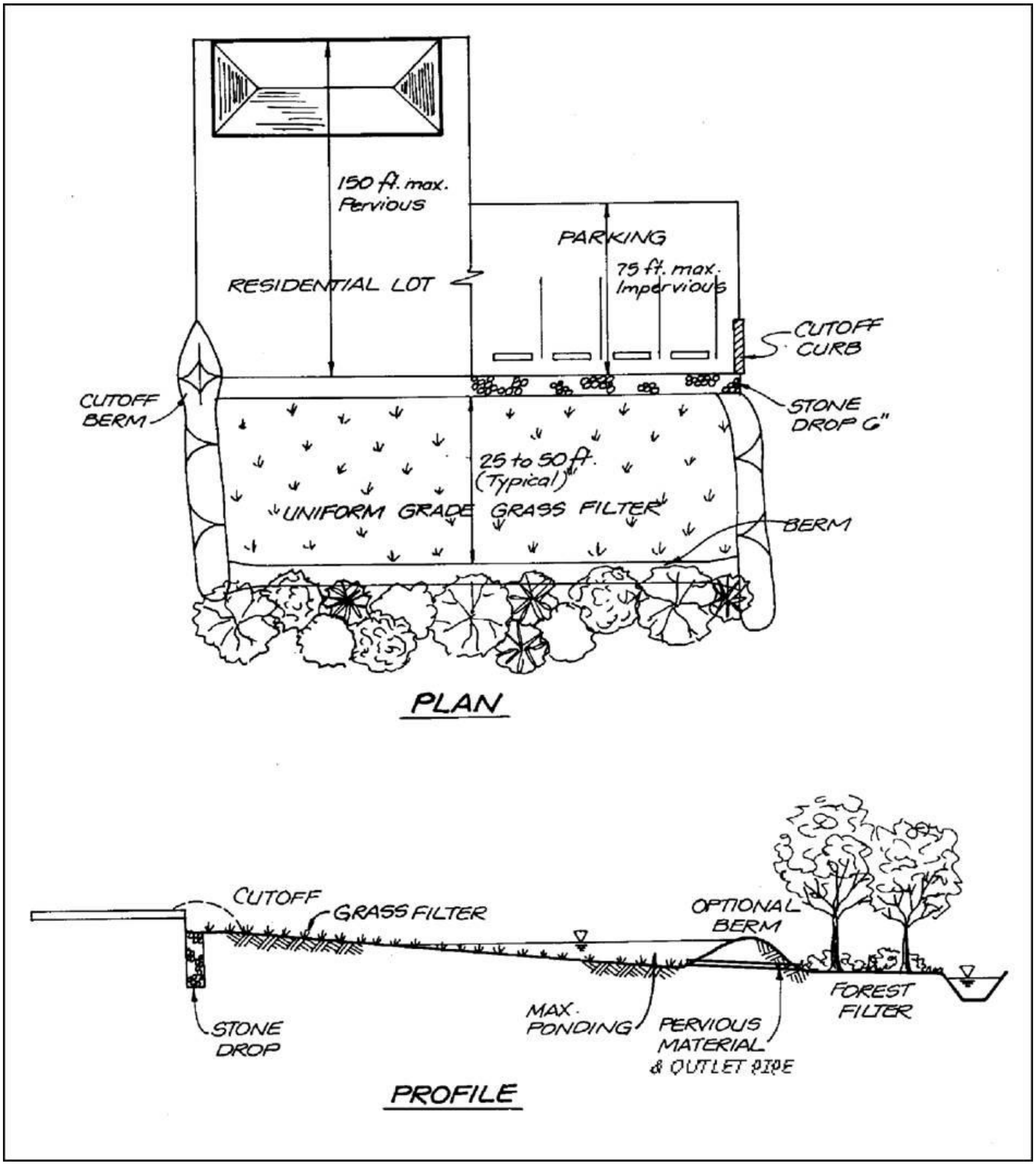


Figure 3.3.1-1 Schematic of Filter Strip (with Berm)

3.3.1.6 Design Example

Basic Data

Small commercial lot 150 feet deep x 100 feet wide located in Columbia County

- Drainage area (A) = 0.34 acres
- Impervious percentage (I) = 70%
- Slope equals 4%, Manning's n = 0.25

Calculate Maximum Discharge Loading Per Foot of Filter Strip Width

Using equation 3.3.1:

$$\mathbf{q = 0.00236 / 0.25 * (1.0)^{5/3} * (4)^{1/2} = 0.019\ cfs / ft}$$

Water Quality Peak Flow

See subsection 2.1.7 for details

Compute the Water Quality Volume in inches:

$$\mathbf{WQ_v = 1.2 (0.05 + 0.009 * 70) = 0.82\ inches}$$

Compute modified CN for 1.2-inch rainfall (P=1.2):

$$\mathbf{CN = 1000 / [10 + 5P + 10Q - 10(Q^2 + 1.25 * Q * P)^{1/2}]}$$

$$\mathbf{= 1000 / [10 + 5 * 1.2 + 10 * 0.82 - 10 (0.82^2 + 1.25 - 0.82 * 1.2)^{1/2}]}$$

$$\mathbf{= 96.09\ (Use\ CN = 96)}$$

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.2 inch storm.

From Section 2.1, I_a = 0.083, therefore $\mathbf{I_a / P = 0.83 / 1.2 = 0.069}$.

For a Type II storm (using the limiting values) q_u = 950 csm/in, and therefore:

$$\mathbf{Q_{wq} = (950\ csm / in) * (0.34\ ac / 640\ ac / mi^2)(0.82") = 0.41\ cfs}$$

Minimum Filter Width

Using equation 3.3.2:

$$\mathbf{W_{fMIN} = Q / q = 0.41 * 0.019 = 22\ feet}$$

Since the width of the lot is 100 feet, the actual width of the filter strip will depend on site grading and the ability to deliver the drainage to the filter strip in sheet flow through a pea gravel filled trench.

Filter without Berm

- 2-year, 24-hour storm (see Appendix A) = 0.16 in/hr or 0.16*24= 3.84 inches
- Use 5 minute travel (contact) time

Using equation 3.3.3:

$$\mathbf{L_f = (5)^{1.25} * (3.84)^{0.625} * (4)^{0.5} / (3.34 * 0.25) = 41\ feet}$$

Note: Reducing the filter strip slope to 2% and planting a denser grass (raising the Manning n to 0.35) would reduce the filter strip length to 21 feet. Sensitivity to slope and Manning's n changes are illustrated for this example in Figure 3.3.1-2.

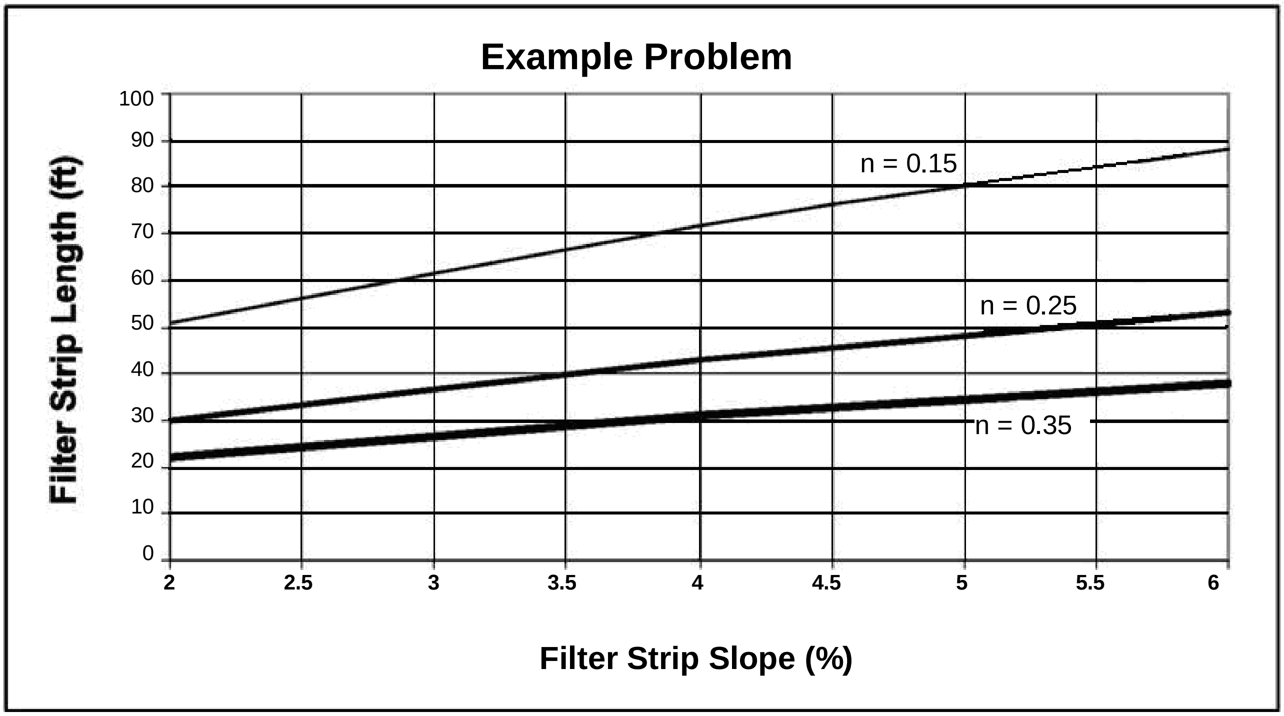


Figure 3.3.1-2 Example Problem Sensitivity of Filter Strip Length to Slope and Manning's n Values

Filter With Berm

- Pervious berm height is 6 inches

Compute the Water Quality Volume in cubic feet:

$$\mathbf{WQ_v = R_v * 1.2/12 * A = (0.05 + 0.009 * 70) * 1.2/12 * 0.34 = 0.023\ Ac - ft\ or\ 1{,}007\ ft^3}$$

For a berm height of 6 inches, the "wedge" of volume captured by the filter strip is:

$$\text{Volume} = \mathbf{W_f / \tfrac{1}{2} * L_f * 0.5 = 0.25\ W_f L_f = 1{,}007\ ft^3}$$

For a maximum width of the filter of 100 feet, the length of the filter would then be <u>40 feet</u>.

For a 1-foot berm height, the length of the filter would be <u>20 feet</u>.

3.3.2 Grass Channel

Limited Application
Structural Stormwater Control

Description: Vegetated open channels designed to filter stormwater runoff and meet velocity targets for the water quality design storm and the 2-year storm event.

REASONS FOR LIMITED USE

- Cannot alone achieve the 80% TSS removal target

KEY CONSIDERATIONS

- Can be used as part of the runoff conveyance system to provide pretreatment
- Grass channels can act to partially infiltrate runoff from small storm events if underlying soils are pervious
- Less expensive than curb and gutter systems
- Should not be used on slopes greater than 4%; slopes between 1% and 2% recommended
- Ineffective unless carefully designed to achieve low flow rates in the channel (< 1.0 ft/s)
- Potential for bottom erosion and resuspension
- Standing water may not be acceptable in some areas

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**

☐ **Channel / Flood Protection**

SPECIAL APPLICATIONS

☑ **Pretreatment**

☐ **High Density / Ultra-Urban**

☑ **Other:** Curb and gutter replacement

Residential Subdivision Use: *Yes*

3.3.2.1 General Description

Grass channels, also termed "biofilters," are typically designed to provide nominal treatment of runoff as well as meet runoff velocity targets for the water quality design storm. Grass channels are well suited to a number of applications and land uses, including treating runoff from roads and highways and pervious surfaces.

Grass channels differ from the enhanced dry swale design in that they do not have an engineered filter media to enhance pollutant removal capabilities and therefore have a lower pollutant removal rate than for a dry or wet (enhanced) swale. Grass channels can partially infiltrate runoff from small storm events in areas with pervious soils. When properly incorporated into an overall site design, grass channels can reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.

When designing a grass channel, the two primary considerations are channel capacity and minimization of erosion. Runoff velocity should not exceed 1.0 foot per second during the peak discharge associated with the water quality design rainfall event, and the total length of a grass channel should provide at least 5 minutes of residence time. To enhance water quality treatment, grass channels must have broader bottoms, lower slopes and denser vegetation than most drainage channels. Additional treatment can be provided by placing check-dams across the channel below pipe inflows, and at various other points along the channel.

3.3.2.2 Pollutant Removal Capabilities

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 50%**
- **Total Phosphorus – 25%**
- **Total Nitrogen – 20%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – 30%**

3.3.2.3 Design Criteria and Specifications

- Grass channels should generally be used to treat small drainage areas of less than 5 acres. If the practices are used on larger drainage areas, the flows and volumes through the channel become too large to allow for filtering and infiltration of runoff.
- Grass channels should be designed on relatively flat slopes of less than 4%; channel slopes between 1% and 2% are recommended.
- Grass channels can be used on most soils with some restrictions on the most impermeable soils. Grass channels should not be used on soils with infiltration rates less than 0.27 inches per hour if infiltration of small runoff flows is intended.
- A grass channel should accommodate the peak flow for the water quality design storm Q_{wq} (see subsection 2.1.7).
- Grass channels should have a trapezoidal or parabolic cross section with relatively flat side slopes (generally 3:1 or flatter).
- The bottom of the channel should be between 2 and 6 feet wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, which is the formation of small channels within the swale bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning's equation. If a larger channel is needed, the use of a compound cross section is recommended.
- Runoff velocities must be nonerosive. The full-channel design velocity will typically govern.
- A 5-minute residence time is recommended for the water quality peak flow. Residence time may be increased by reducing the slope of the channel, increasing the wetted perimeter, or planting a denser grass (raising the Manning’s n).
- The depth from the bottom of the channel to the groundwater should be at least 2 feet to prevent a moist swale bottom, or contamination of the groundwater.
- Incorporation of check dams within the channel will maximize retention time.
- Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods. See Appendix F for a list of appropriate grasses for use in Georgia.

See Section 4.4 (*Open Channel Design*) for more information and specifications on the design of grass channels.

Grass Channels for Pretreatment

A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a grass channel as a pretreatment measure. The length of the grass channel depends on the drainage area, land use, and channel slope. Table 3.3.2-1 provides sizing guidance for grass channels for a 1-acre drainage area. The minimum grassed channel length should be 20 feet.

Parameter	<= 33% Impervious		Between 34% and 66% Impervious		>= 67% Impervious	
Slope (max = 4%)	< 2%	>2%	< 2%	>2%	< 2%	>2%
Grass channel minimum length* (feet) * assumes 2-foot wide bottom width	25	40	30	45	35	50

Table 3.3.2-1 Bioretention Grass Channel Sizing Guidance
(Source: Claytor & Schueler, 1996)

3.3.2.4 Inspection and Maintenance Requirements

Activity	Schedule
• Mow grass to maintain a 3- to 4-inch height.	As needed (frequently / seasonally)
• Remove sediment build-up within the bottom of the grass channel once it has accumulated to 25% of the original design volume.	As needed (infrequently)
• Inspect grass along side slopes for erosion and formation of rills or gullies and correct. • Remove trash and debris accumulated in the channel. • Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established.	Annually (Semi-annually first year)

Table 3.3.2-2 Typical Maintenance Activities for Grass Channels
(Source: Adapted from CWP, 1996)

3.3.2.5 Example Schematics

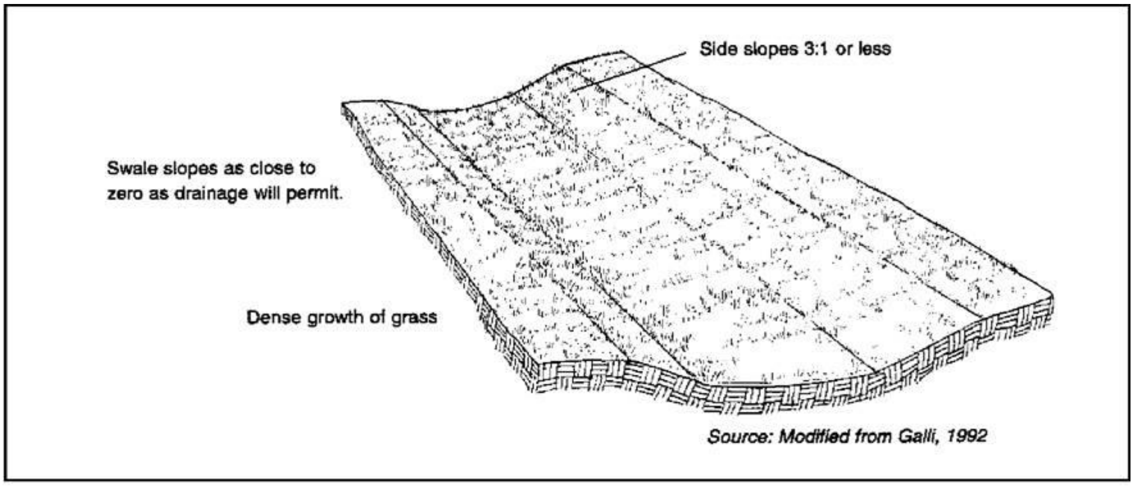


Figure 3.3.2-1 Typical Grass Channel

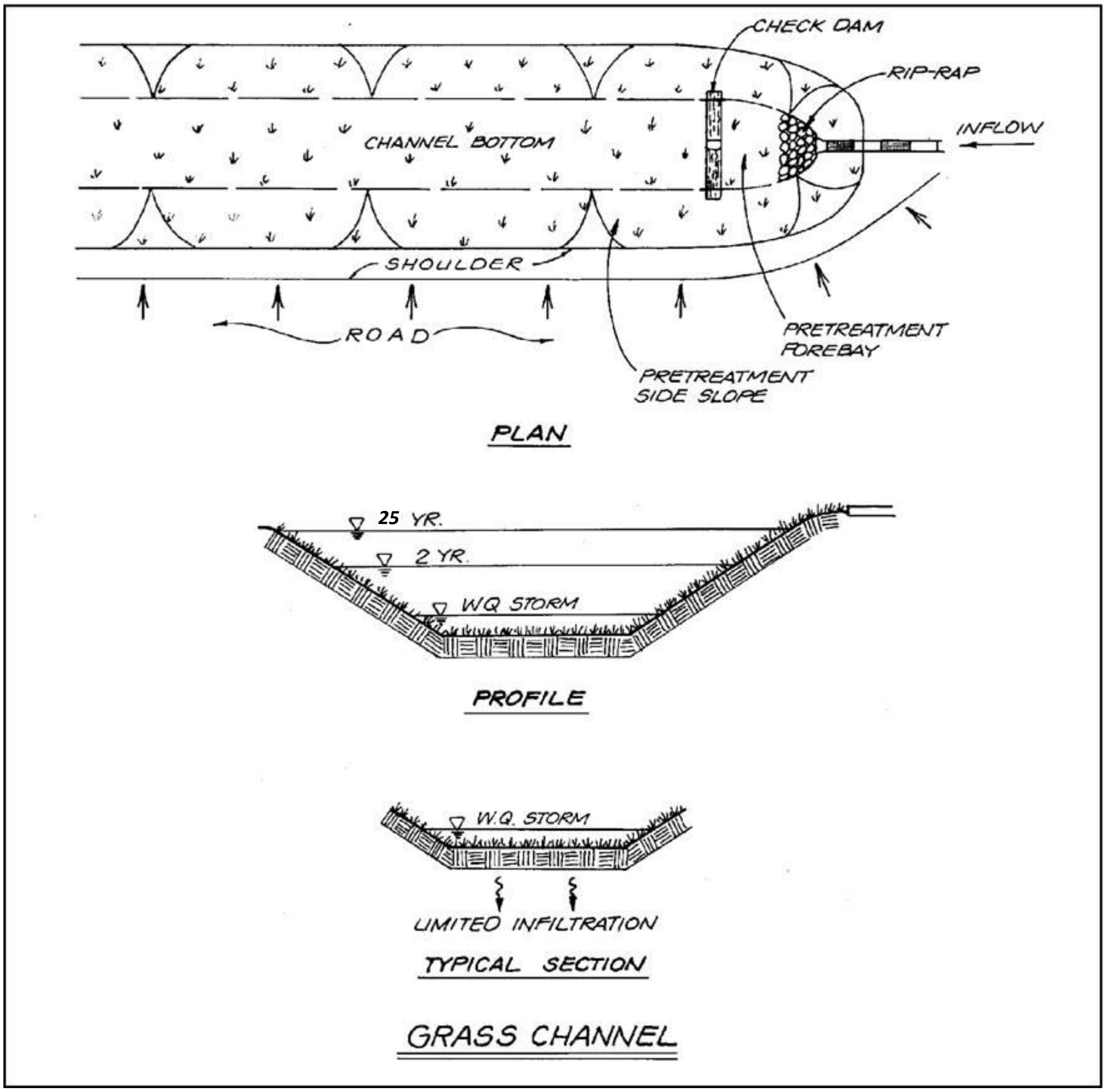


Figure 3.3.2-2 Schematic of Grass Channel

3.3.2.6 Design Example

Basic Data

Small commercial lot 300 feet deep x 145 feet wide located in Athens

- Drainage area (A) = 1.0 acres
- Impervious percentage (I) = 70%

Water Quality Peak Flow

See subsection 2.1.7 for details

Compute the Water Quality Volume in inches:

$$\mathbf{WQ_v = 1.2\ (0.05 + 0.009 * 70) = 0.82\ inches}$$

Compute modified CN for 1.2-inch rainfall (P=1.2):

$$\begin{aligned}\mathbf{CN} &= \mathbf{1000/[10 + 5P + 10Q - 10(Q^2 + 1.25 * Q * P)^{1/2}]} \\ &= \mathbf{1000/[10 + 5 * 1.2 + 10 * 0.82 - 10(0.82^2 + 1.25 - 0.82 * 1.2)^{1/2}]} \\ &= \mathbf{96.09\ (Use\ CN = 96)}\end{aligned}$$

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.2-inch storm.

From Figure 2.1.5-3, I_a = 0.083, therefore $\mathbf{I_a / P = 0.83 / 1.2 = 0.069}$.

From Figure 2.1.5-6 for a Type II storm (using the limiting values) q_u = 950 csm/in, and therefore:

$$\mathbf{Q_{wq} = (950\ csm/in) * (1.0\ ac / 640\ ac/mi^2)(0.82") = 1.22\ cfs}$$

Utilize Q_{wq} to Size the Channel

The maximum flow depth for water quality treatment should be approximately the same height of the grass. A maximum flow depth of 4 inches is allowed for water quality design. A maximum flow velocity of 1.0 foot per second for water quality treatment is required. For Manning's n use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass. Site slope is 2%.

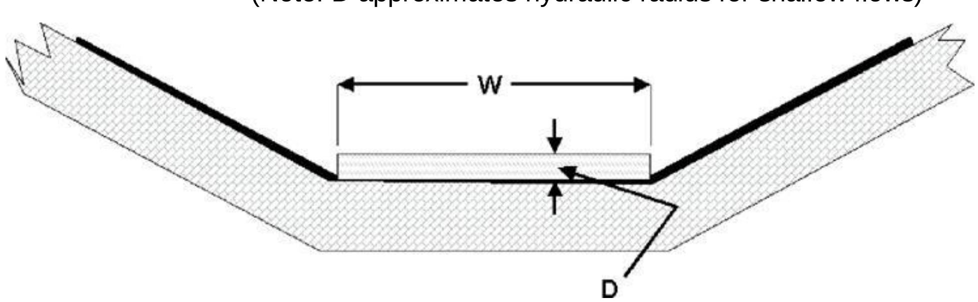
Input variables: n = 0.15
S = 0.02 ft/ft
D = 4/12 = 0.33 ft

Then: $\mathbf{Q_{wq} = Q = VA = 1.49 / n\ D^{2/3} S^{1/2} DW}$

Where:

Q	=	peak flow (cfs)
V	=	velocity (ft/sec)
A	=	flow area (ft^2) = WD
W	=	channel bottom width (ft)
D	=	flow depth (ft)
S	=	slope (ft/ft)

(Note: D approximates hydraulic radius for shallow flows)



Then for a known n, Q, D and S minimum width can be calculated.

$$\mathbf{(nQ)/(1.49\ D^{5/3}S^{1/2}) = W = (0.15 * 1.22)/(1.49 * 0.33^{5/3}\ * 0.02^{1/2}) = 5.5\ ft\ minimum}$$

$$\mathbf{V = Q/(WD) = 1.22/(4.0 * 4/12) = 0.92\ fps\ (okay)}$$

(Note: WD approximates flow area for shallow flows.)

Minimum length for 5-minute residence time, L = V * (5*60) = 201 feet

Depending on the site geometry, the width or slope or density of grass (Manning's n value) might be adjusted to slow the velocity and shorten the channel in the next design iteration. For example, using a 9.3-foot bottom width* of flow and a Manning's n of 0.25, solve for new depth and length.

$$\mathbf{Q = VA = 1.49/n\ D^{5/3}S^{1/2}W}$$

$$\mathbf{D = [(Q * n)/(1.49 * S^{1/2}\ * W)]^{3/5}}$$

$$\mathbf{= [(1.22 * 0.25)/(1.49 * 0.02^{1/2}\ * 9.3)]^{3/5}\ = 0.33\ ft = 4"\ (okay)}$$

$$\mathbf{V = Q/WD = 1.22 * (9.3 * 0.33) = 0.40\ feet\ per\ second}$$

$$\mathbf{L = V * 5 * 60 = 120\ feet}$$

** In this case a dividing berm should be used to control potential braiding.*

Refer to Section 4.4 (*Open Channel Design*) to complete the grass channel design for a specified design storm event.

Regular inspection and maintenance is critical to the effective operation of grass channels as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.3.3 Underground Sand Filter

Limited Application
Structural Stormwater Control

Description: Design variant of the sand filter located in an underground vault.

REASONS FOR LIMITED USE

- Intended for space-limited applications
- High maintenance requirements

KEY CONSIDERATIONS

- High pollutant removal capability
- Filter may require more frequent maintenance than most of the other stormwater controls
- High removal rates for sediment, BOD, and fecal coliform bacteria
- Precast concrete shells available, which decrease construction costs

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**

☐ **Channel / Flood Protection**

SPECIAL APPLICATIONS

☐ **Pretreatment**

☑ **High Density / Ultra-Urban**

☑ **Other:** Curb and gutter replacement

Residential Subdivision Use: *No*

3.3.3.1 General Description

The underground sand filter is a design variant of the sand filter located in an underground vault designed for high-density land use or ultra-urban applications where there is not enough space for a surface sand filter or other structural stormwater controls.

The underground sand filter is a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into a third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Due to its location below the surface, underground sand filters have a high maintenance burden and should only be used where adequate inspection and maintenance can be ensured.

3.3.3.2 Pollutant Removal Capabilities

Underground sand filter pollutant removal rates are similar to those for surface and perimeter sand filters (see subsection 3.2.4, *Sand Filters*).

3.3.3.3 Design Criteria and Specifications

- Underground sand filters are typically used on highly impervious sites of 1 acre or less. The maximum drainage area that should be treated by an underground sand filter is 5 acres.
- Underground sand filters are typically constructed on-line, but can be constructed off-line. For off-line construction, the overflow between the second and third chambers is not included.
- The underground vault should be tested for water tightness prior to placement of filter layers.
- Adequate maintenance access must be provided to the sedimentation and filter bed chambers.
- Compute the minimum wet pool volume required in the sedimentation chamber as:
  $$\mathbf{V_w = A_s * 3 \text{ feet minimum}}$$
- Consult the design criteria for the perimeter sand filter (see Section 3.2.4) for the rest of the underground filter sizing and design steps.

3.3.3.4 Inspection and Maintenance Requirements

Activity	Schedule
• Monitor water level in sand filter chamber.	Quarterly and following large storm events
• Sedimentation chamber should be cleaned out when the sediment depth reaches 12 inches.	As needed
• Remove accumulated oil and floatables in sedimentation chamber.	As needed, (typically every 6 months)

Table 3.3.3-1 Typical Maintenance Activities for Underground Sand Filters
(Source: CWP, 1996)

Additional inspection and maintenance requirements for underground sand filters are similar to those for surface sand filter facilities (see subsection 3.2.4)

3.3.3.5 Example Schematic

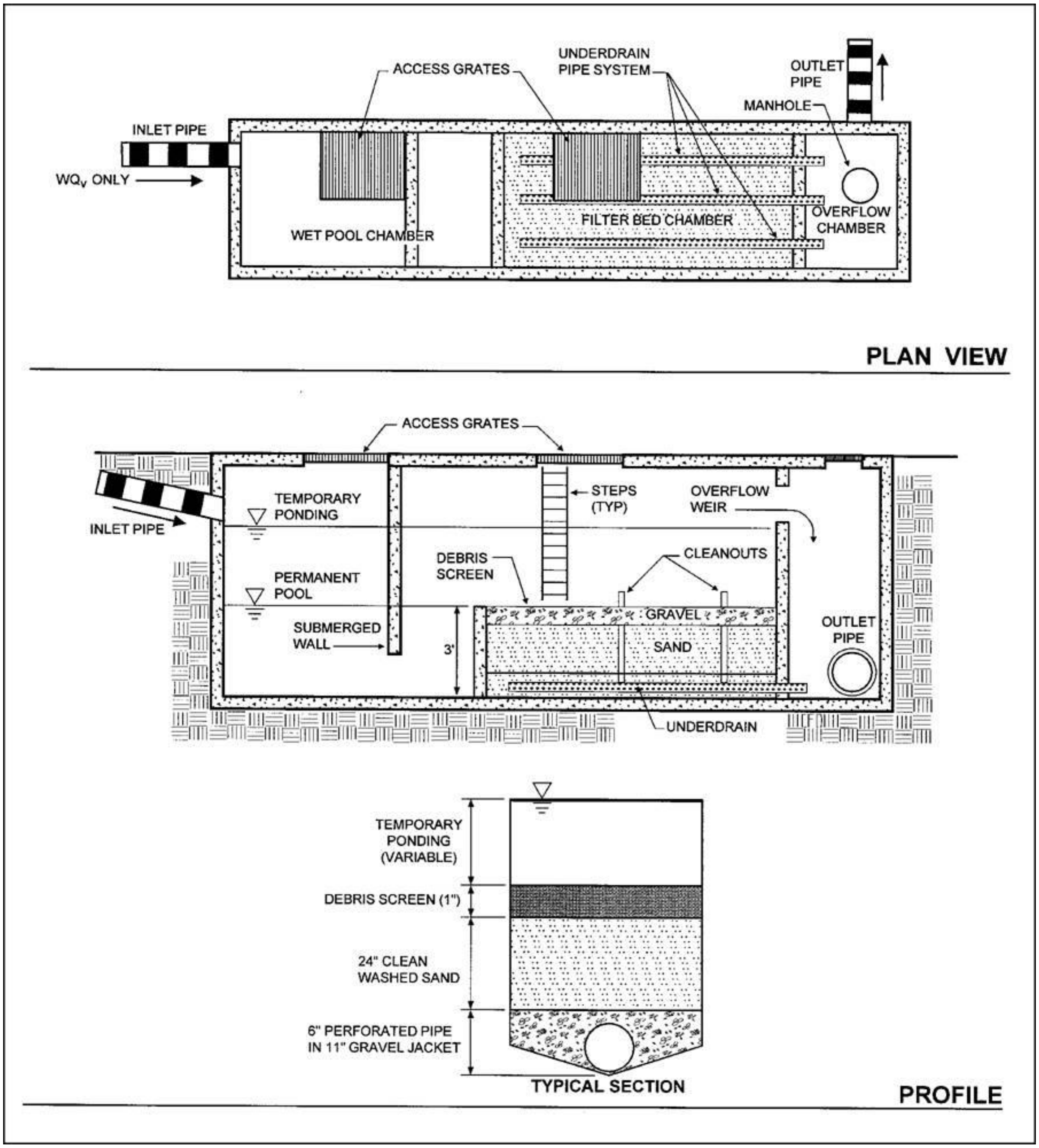


Figure 3.3.3-1 Schematic of Underground Sand Filter
(Source: Center for Watershed Protection)

3.3.4 Submerged Gravel Wetlands

Limited Application
Structural Stormwater Control

Description: One or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

REASONS FOR LIMITED USE	STORMWATER MANAGEMENT SUITABILITY
• Intended for space-limited applications • High maintenance requirements	☑ **Water Quality** ☐ **Channel / Flood Protection**
KEY CONSIDERATIONS	**SPECIAL APPLICATIONS**
• Generally requires low land consumption, and can fit within an area that is typically devoted to landscaping • High pollutant removal capabilities are expected; however, limited performance data exist • Can be located in low-permeability soils with a high water table • Periodic sediment removal required to prevent clogging of gravel base	☐ **Pretreatment** ☑ **High Density / Ultra-Urban** ☑ **Other:** Hotspot areas **Residential Subdivision Use:** *No*

3.3.4.1 General Description

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

3.3.4.2 Pollutant Removal Capabilities

The pollution removal efficiency of the submerged gravel wetland is similar to a typical wetland. Recent data show a TSS removal rate in excess of the 80% goal. This reflects the settling environment of the gravel media. These systems also exhibit removals of about 60% TP, 20% TN and 50% Zn. The growth of algae and microbes among the gravel media has been determined to be the primary removal mechanism of the submerged gravel wetland.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 50%**
- **Total Nitrogen – 20%**
- **Fecal Coliform – 70%**
- **Heavy Metals – 50%**

3.3.4.3 Design Criteria and Specifications

- Submerged gravel wetlands should be designed as off-line systems designed to handle only water quality volume.
- Submerged gravel wetland systems need sufficient drainage area to maintain vegetation. See subsection 2.1.8 for guidance on performing a water balance calculation.
- The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
- All submerged gravel wetland designs should include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- Unless they receive hotspot runoff, submerged gravel wetland systems can be allowed to intersect the groundwater table.
- Guidance on establishing wetland vegetation can be found in Appendix F, *Landscaping and Aesthetics Guidance*.
- See subsection 3.2.2 (*Stormwater Wetlands*) for additional planning and design guidance.

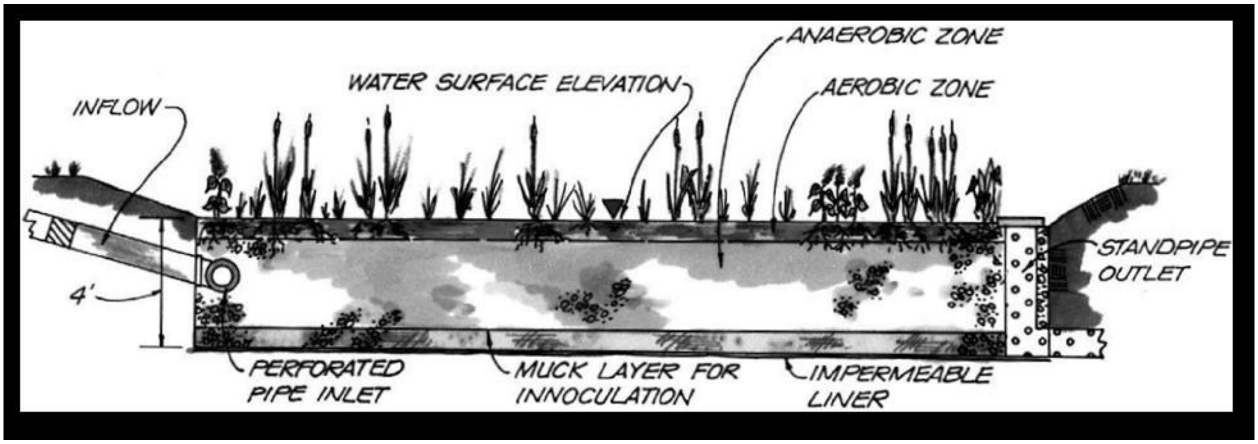
3.3.4.4 Inspection and Maintenance Requirements

Activity	Schedule
• Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged.	Monthly
• Check for sediment buildup in gravel bed.	Annual Inspection
• If sediment buildup is preventing flow through the wetland, remove gravel and sediment from cell. Replace with clean gravel and replant vegetation.	As Needed

Table 3.3.4-1 Typical Maintenance Activities for Submerged Gravel Wetland Systems

Additional inspection and maintenance requirements for submerged gravel wetland systems are similar to those for stormwater wetlands (see subsection 3.2.2).

3.3.4.5 Example Schematic



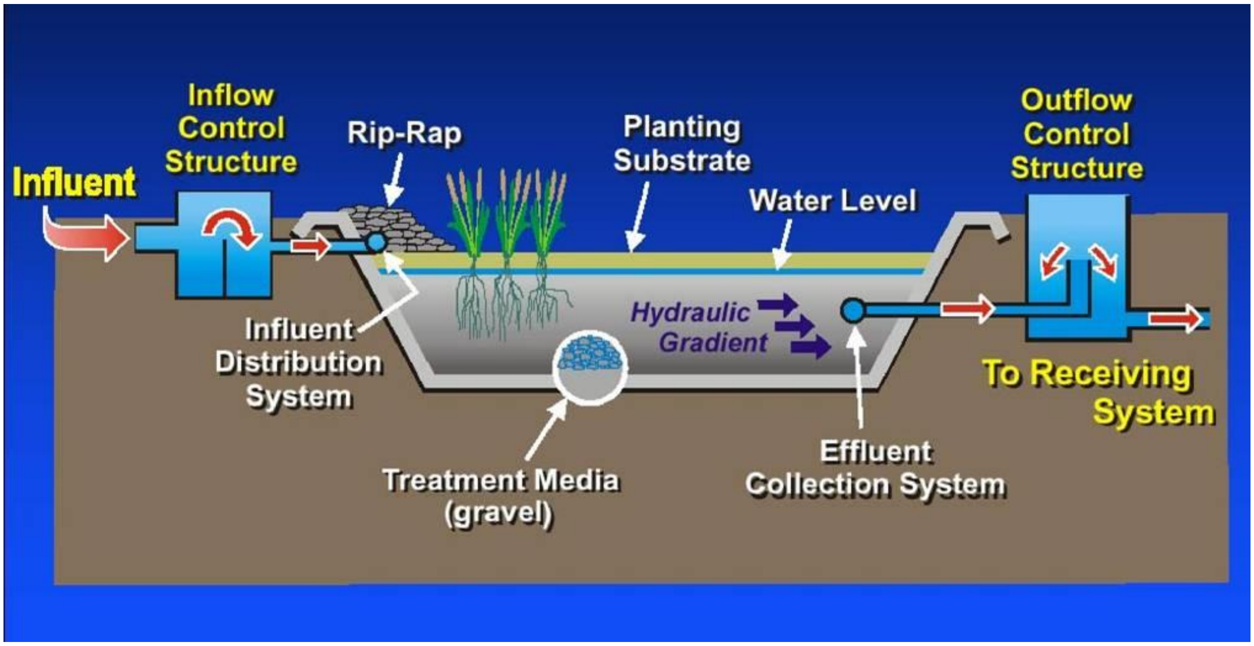
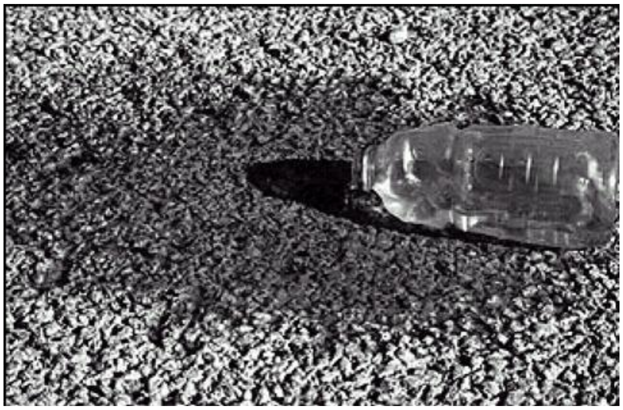


Figure 3.3.4-1 Schematics of Submerged Gravel Wetland System
(Sources: Center for Watershed Protection; Roux Associates Inc.)

3.3.5 Porous Concrete

Limited Application
Structural Stormwater Control



Description: Porous concrete is the term for a mixture of coarse aggregate, portland cement and water that allow for rapid infiltration of water and overlays a stone aggregate reservoir. This reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system.

REASONS FOR LIMITED USE

- Traditionally high failure rate and short life span
- Intended for low volume auto traffic areas, or for overflow parking applications
- High maintenance requirements
- Special attention to design and construction needed
- Should not be used in areas of soils with low permeability, well head protection zones, or recharge areas of water supply aquifer recharge areas
- Restrictions on use by heavy vehicles

KEY CONSIDERATIONS

- Soil infiltration rate of 0.5 in/hr or greater required
- Excavated area filled with stone media; gravel and sand filter layers with observation well
- Pre-treat runoff if sediment present
- Provides reduction in runoff volume
- Somewhat higher cost when compared to conventional pavements
- Potential for high failure rate if poorly designed, poorly constructed, not adequately maintained or used in unstabilized areas
- Potential for groundwater contamination

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**
✪ **Channel / Flood Protection**

SPECIAL APPLICATIONS

☐ **Pretreatment**
☑ **High Density / Ultra-Urban**
☑ **Other:** Overflow Parking, Driveways & related uses

Residential Subdivision Use: *Yes*
(in common areas that are maintained)

✪ in certain situations

3.3.5.1 General Description

Porous concrete (also referred to as *enhanced porosity concrete*, *porous concrete*, *portland cement pervious pavement* and *pervious pavement*) is a subset of a broader family of pervious pavements including porous asphalt, and various kinds of grids and paver systems. Porous concrete is thought to have a greater ability than porous asphalt to maintain its porosity in hot weather and thus is provided as a limited application control. Although, porous concrete has seen growing use in Georgia, there is still very limited practical experience with this measure. According to the U.S. EPA, porous pavement sites have had a high failure rate – approximately 75 percent. Failure has been attributed to poor design, inadequate construction techniques, and soils with low permeability, heavy vehicular traffic and poor maintenance. This measure, if used, should be carefully monitored over the life of the development.

Porous concrete consists of a specially formulated mixture of portland cement, uniform, open graded course aggregate, and water. The concrete layer has a high permeability often many times that of the underlying permeable soil layer, and allows rapid percolation of rainwater through the surface and into the layers beneath. The void space in porous concrete is in the 15% to 22% range compared to three to five percent for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff.

Porous concrete is designed primarily for stormwater quality, i.e. the removal of stormwater pollutants. However, they can provide limited runoff quantity control, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the channel protection volume (Cp_v) in addition to WQ_v. Porous concrete will need to be used in conjunction with another structural control to provide overbank and extreme flood protection, if required.

Modifications or additions to the standard design have been used to pass flows and volumes in excess of the water quality volume, or to increase storage capacity or treatment. These include:

- Placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled
- Providing surface detention storage in a parking lot, adjacent swale, or detention pond with suitable overflow conveyance
- Connecting the stone reservoir layer to a stone filled trench
- Adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume
- Placing an underground detention tank or vault system beneath the layers

The infiltration rate of the soils in the sub-grade should be adequate to support drawdown of the entire runoff capture volume within 24 to 48 hours. Special care must be taken during construction to avoid undue compaction of the underlying soils which could affect the soils' infiltration capability.

Porous concrete systems are typically used in low-traffic areas such as the following types of applications:

- Parking pads in parking lots
- Overflow parking areas
- Residential street parking lanes
- Recreational trails
- Golf cart and pedestrian paths
- Emergency vehicle and fire access lanes

Slopes should be flat or gentle to facilitate infiltration versus runoff and the seasonally high water table or bedrock should be a minimum of two feet below the bottom of the gravel layer if infiltration is to be relied on to remove the stored volume.

Porous concrete has the positive characteristics of volume reduction due to infiltration, groundwater recharge, and an ability to blend into the normal urban landscape relatively unnoticed. It also allows a reduction in the cost of other stormwater infrastructure, a fact that may offset the greater placement cost somewhat.

A drawback is the cost and complexity of porous concrete systems compared to conventional pavements. Porous concrete systems require a very high level of construction workmanship to ensure that they function as designed. They experience a high failure rate if they are not designed, constructed and maintained properly.

Like other infiltration controls, porous concrete should not be used in areas that experience high rates of wind erosion or in drinking water aquifer recharge areas.

3.3.5.2 Pollutant Removal Capabilities

As they provide for the infiltration of stormwater runoff, porous concrete systems have a high removal of both soluble and particulate pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. Due to the potential for clogging, porous concrete surfaces should not be used for the removal of sediment or other coarse particulate pollutants.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – not applicable**
- **Total Phosphorus – 50%**
- **Total Nitrogen – 65%**

- **Fecal Coliform – insufficient data**
- **Heavy Metals – 60%**

Pollutant removal can be improved through routine vacuum sweeping and high pressure washing, insuring a drainage time of at least 24 hours, pretreating the runoff, having organic material in the subsoil, and using clean washed aggregate (EPA, 1999).

3.3.5.3 Design Criteria and Specifications

- Porous concrete systems can be used where the underlying in-situ sub-soils have an infiltration rate greater than 0.5 inches per hour. Therefore, porous concrete systems are not suitable on sites with hydrologic group D or most group C soils, or soils with a high (> 30%) clay content. During construction and preparation of the sub-grade, special care must be taken to avoid compaction of the soils.
- Porous concrete systems should typically be used in applications where the pavement receives tributary runoff only from impervious areas. Actual pervious surface area sizing will depend on achieving a 24-hour minimum and 48-hour maximum draw down time for the design storm volume.
- If runoff is coming from adjacent pervious areas, it is important that those areas be fully stabilized to reduce sediment loads and prevent clogging of the porous paver surface. Pretreatment using filter strips or vegetated swales for removal of course sediments are recommended. (see sections 3.3.1 and 3.3.2)
- Porous concrete systems should not be used on slopes greater than 5% with slopes of no greater than 2% recommended. For slopes greater than 1% barriers perpendicular to the direction of drainage should be installed in sub-grade material to keep it from washing away, or filter fabric should be placed at the bottom and sides of the aggregate to keep soil from migrating into the aggregate and reducing porosity.
- A minimum of four feet of clearance is recommended between the bottom of the gravel base course and underlying bedrock or the seasonally high groundwater table.
- Porous concrete systems should be sited at least 10 feet down-gradient from buildings and 100 feet away from drinking water wells.
- To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities must not be infiltrated. Porous concrete should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals. In addition, porous concrete should not be considered for areas with a high pesticide concentration. Porous concrete is also not suitable in areas with karst geology without adequate geotechnical testing by qualified individuals and in accordance with Columbia County requirements.
- Porous concrete system designs must use some method to convey larger storm event flows to the conveyance system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but would accept bypass flows that are too large to be infiltrated by the porous concrete system, or if the surface clogs.
- For the purpose of sizing downstream conveyance and structural control system, porous concrete surface areas can be assumed to 45% impervious. For other values, submit supporting data to Columbia County for review and approval. In addition, credit can be taken for the runoff volume infiltrated from other impervious areas using the methodology in Section 3.1.
- For treatment control, the design volume should be, at a minimum, equal to the water quality volume. The water quality storage volume is contained in the surface layer, the aggregate reservoir, and the sub-grade above the seasonal high water table – if the sub-grade is sandy. The storm duration (fill time) is normally short compared to the infiltration rate of the sub-grade; duration of <u>two hours</u> can be used for design purposes. The total storage volume in a layer is equal to the percent of voids times the volume of the layer. Alternately storage may be created on the surface through temporary ponding, though this would tend to accelerate clogging if course sediment or mud settles out on the surface.

- The cross-section typically consists of four layers, as shown in Figure 3.3.5-1. The aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Descriptions of each of the layers is presented below:

  <u>Porous Concrete Layer</u> – The porous concrete layer consists of an open-graded concrete mixture usually ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous concrete can be assumed to contain 18 percent voids (porosity = 0.18) for design purposes. Thus, for example, a 4-inch thick porous concrete layer would hold 0.72 inches of rainfall. The omission of the fine aggregate provides the porosity of the porous pavement. To provide a smooth riding surface and to enhance handling and placement a coarse aggregate of ⅜-inch maximum size is normally used. Use GDOT No. 8 coarse aggregate (⅜ to No. 16) per ASTM C 33 or No. 89 coarse aggregate (⅜ to No. 50) per ASTM D 448. See the GCPA specifications (referenced).

  <u>Top Filter Layer</u> – Consists of a 0.5 inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt layer. Can be combined with reservoir layer using suitable stone.

  <u>Reservoir Layer</u> – The reservoir gravel base course consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40% (GADOT No.3 Stone). The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer should be designed to drain completely in 48 hours. Also, the layer should be designed to store at a minimum the water quality volume (WQ_v). Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist. .

  <u>Bottom Filter Layer</u> – The surface of the sub-grade should be a 6-inch layer of sand (ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) or a 2 inch thick layer of 0.5 inch crushed stone, and be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

  <u>Filter Fabric</u> – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity. Fabric should be MIRFI # 14 N or equivalent.

  <u>Underlying Soil</u> – The underlying soil should have an infiltration capacity of at least 0.5 in/hr, but preferably greater than 0.50 in/hr. as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full infiltration system. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at sub-grade elevation to determine the impermeable layer, and, for safety, one-half the measured value is allowed for infiltration calculations.

- The pit excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench should not be loaded so as to cause compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be protected during site construction, and should be constructed after upstream areas have been stabilized.

- An observation well consisting of perforated PVC pipe 4 to 6 inches in diameter should be placed at the downstream end of the facility and protected. The well should be used to determine actual infiltration rates.
- A warning sign should be placed at the facility that states, “Porous Paving used on this site to reduce pollution. Do not resurface with non-porous material.
- Details of construction of the concrete layer are beyond the scope of this manual. However, construction of porous concrete is exacting, and requires special handling, timing, and placement to perform adequately. Porous concrete can only be installed by a contractor approved by Columbia County and trained in porous concrete installation.

3.3.5.4 Inspection and Maintenance Requirements

Activity	Schedule
• Initial inspection	Monthly for three months after installation
• Ensure that the porous paver surface is free of sediment	Monthly
• Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed	As needed, based on inspection
• Vacuum sweep porous concrete surface followed by high pressure hosing to keep pores free of sediment	Four times a year
• Inspect the surface for deterioration or spalling • Check to make sure that the system dewaters between storms	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet • Rehabilitation of the porous concrete system, including the top and base course as needed	Upon failure

Table 3.3.5-1 Typical Maintenance Activities for Porous Concrete Systems

To ensure proper maintenance of porous pavement, a carefully worded maintenance agreement is essential. It should include specific the specific requirements and establish the responsibilities of the property owner and provide for enforcement.

3.3.5.5 Example Schematics

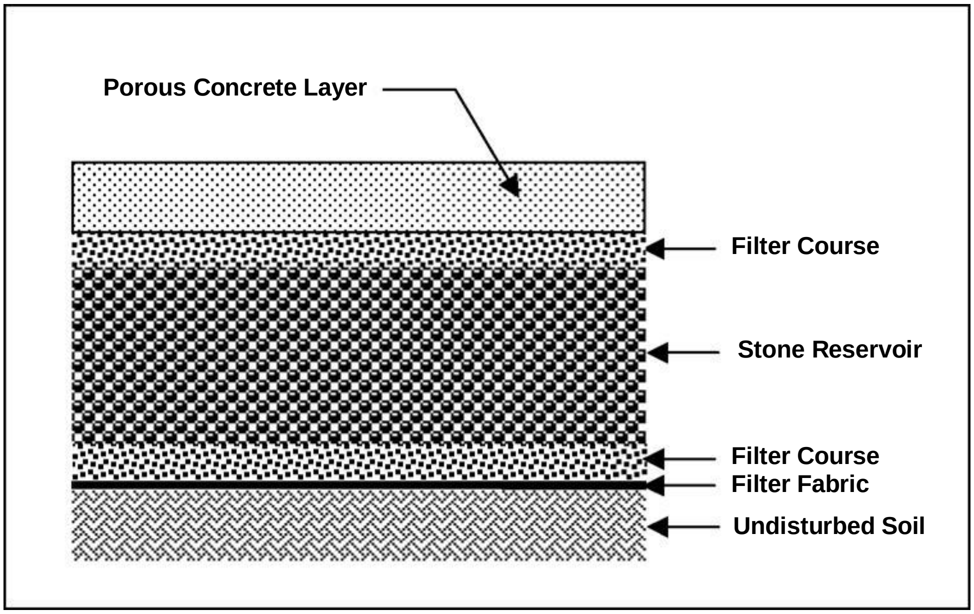


Figure 3.3.5-1 Porous Concrete System Section
(Modified From: LAC 2000)

Figure 3.3.5-2 Porous Concrete System Installation

Figure 3.3.5-3 Typical Porous Concrete System Applications
(Photos by Bruce Ferguson, Don Wade)

3.3.5.6 Design Example

** Data used in this example is not site specific. Site specific data will be required for actual design. **

Data

A 1.5 acre overflow parking area is to be designed to provide water quality treatment using porous concrete for at least part of the site to handle the runoff from the whole overflow parking area. Initial data shows:

- Borings show depth to water table is 5.0 feet
- Boring and infiltrometer tests show sand-loam with percolation rate (k) of 1.02 inches/hr
- Structural design indicates the thickness of the porous concrete must be at least three inches

Water Quality Volume

$$\mathbf{R_v = 0.05 + 0.009\ I} \quad \text{(where I = 100 percent)}$$
$$\mathbf{= 0.95}$$

$$\mathbf{WQ_v = 1.2\ R_v\ A / 12 = 1.2 * 0.95 * 1.5 / 12} \quad \text{(converted to cubic feet from acre-feet)}$$
$$\mathbf{= 6{,}207\ cubic\ feet}$$

Surface Area

A porosity value n = 0.32 should be used for the gravel and 0.18 for the concrete layer.

All infiltration systems should be designed to fully de-water the entire WQ_v within 24 to 48 hours after the rainfall event at the design percolation rate.

A fill time T = 2 hours can be used for most designs

Chose a depth of gravel pit of three feet (including layer under concrete) which fits the site with a two foot minimum to water table (other lesser depths could be chosen, making the surface area larger). The minimum surface area of the trench can be determined, in a manner similar to the infiltration trench, from the following equation:

$$\mathbf{A = WQ_v / (n_g d_g + kT / 12 + n_p d_p)}$$
$$\mathbf{= 6{,}207 / (0.32 * 3 + 1.02 * 2 / 12 + 0.18 * 3 / 12)}$$
$$\mathbf{= 5{,}283\ square\ feet}$$

Where:

A = Surface Area

WQ_v = Water Quality Volume (or total volume to be infiltrated)

n = porosity (g of the gravel, p of the concrete layer)

d = depth or gravel layer (feet) (g of the gravel, p of the concrete layer)

k = percolation (inches/hour)

T = Fill Time (time for the practice to fill with water), in hours

Check of drain time:

depth = 3*12 + 3 inches to sand layer = 39 inches @ 1.02 in/hr = 38 hours (ok)

Overflow will be carried across the porous concrete and tied into the drainage system for the rest of the site.

3.3.6 Proprietary Structural Controls

Limited Application
Structural Stormwater Control

Description: Manufactured structural control systems available from commercial vendors designed to treat stormwater runoff and / or provide water quantity control.

REASONS FOR LIMITED USE	STORMWATER MANAGEMENT SUITABILITY
Depending on the propriety system, there may be: • Limited performance data • Application constraints • High maintenance requirements • Higher costs than other structural control alternatives	✶ **Water Quality** ✶ **Channel / Flood Protection**
KEY CONSIDERATIONS	**SPECIAL APPLICATIONS**
• Independent performance data must be available to prove a demonstrated capability of meeting stormwater management goal(s) • System or device must be appropriate for use in Georgia conditions, and specifically for the community in question • Installation and operations / maintenance requirements must be understood by all parties approving and using the system or device in question.	✶ **Pretreatment** ✶ **High Density / Ultra-Urban** ✶ **Other:** **Residential Subdivision Use:** ✶ ✶ in certain situations

Note: It is the policy of this Manual not to recommend any specific commercial vendors for proprietary systems.

3.3.6.1 General Description

There are many types of commercially-available proprietary stormwater structural controls available for both water quality treatment and quantity control. These systems include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural control alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and may have high maintenance requirements. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

3.3.6.2 Guidelines for Using Proprietary Systems

In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the stormwater management goals for which it is being intended. This means that the system must provide:

(1) Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection)

(2) Proven record of longevity in the field

(3) Proven ability to function in Columbia County conditions (e.g., climate, rainfall patterns, soil types, etc.)

For a propriety system to meet (1) above for water quality goals, the following monitoring criteria should be met for supporting studies:

- At least 15 storm events must be sampled
- The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification)
- The study must be conducted in the field, as opposed to laboratory testing
- Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device
- Concentrations reported in the study must be flow-weighted
- The propriety system or device must have been in place for at least one year at the time of monitoring

Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions.

Columbia County may submit a proprietary system to further scrutiny, based on the performance of similar practices. A poor performance record or high failure rate is valid justification for not allowing the use of a proprietary system or device.